5.—THE GEOLOGY OF THE DARLING SCARP AT RIDGE HILL

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CONTENTS.

I. INTRODUCTION.

The Darling Scarp which forms the western edge of the Darling Plateau has generally been regarded as a fault scarp (Saint-Smith, 1912, p. 70; Jutson, 1912, p. 149 and 1934, p. 86) but closer examination of some critical areas in recent years throws some doubt on this hypothesis. Thus the slaty rocks at Armadale considered by Saint-Smith (1912, p. 71) to be evidence of the Darling Fault have, on closer examination (Prider, 1941, p. 52), yielded evidence that the earth movements recorded in these rocks are exactly the opposite of that required by the Darling "Fault". A characteristic feature of the Darling Scarp in the vicinity of Perth is a laterite-covered shelf at an elevation of approximately 200 feet above sea-level (Woolnough, 1920, p. 16) which Woolnough calls the Ridge Hill Shelf and which he considers is a step-faulted portion of the high- level laterite (Darling) plateau and thus confirmatory evidence of the Darling Fault which he supposes is a step fault. Further, in his article "The physiographic significance of laterite in Western Australia" (1918, p. 390) he puts forward the general conclusion that "*extraordinary differences in laterite level in adjacent areas indicate block faulting*," citing as evidence the laterite-covered Ridge Hill Shelf. These conclusions appear to be based on the supposition that the high-level laterite on the Darling Plateau which is exposed at an elevation of approximately 700 feet on Gooseberry Hill to the east of the Ridge Hill Shelf is the same as the laterite covering the Ridge Hill Shelf (at an elevation of approximately 250 feet). No detailed investigation of these laterites has previously been made and in order to test Woolnough's conclusions and to obtain further information about the vexed question of the origin of the low-level laterite and of the Darling Scarp a detailed survey of an area of approximately two square miles in the vicinity of Ridge Hill has been made by senior students of the Department of Geology of the University of Western Australia working under the author's guidance. In the course of this survey (made in part by plane table - telescopic alidade and in part by chain-compass-barometer methods) further study was made of the Pre-Cambrian complex of the Darling Range, a group of previously unrecorded sedimentary rocks was discovered, the relationships of the high- and low-level laterites were examined and an investigation into the origin of the extensive sand areas fronting the Darling Scarp was made. The present paper sets out the results of these investigations.

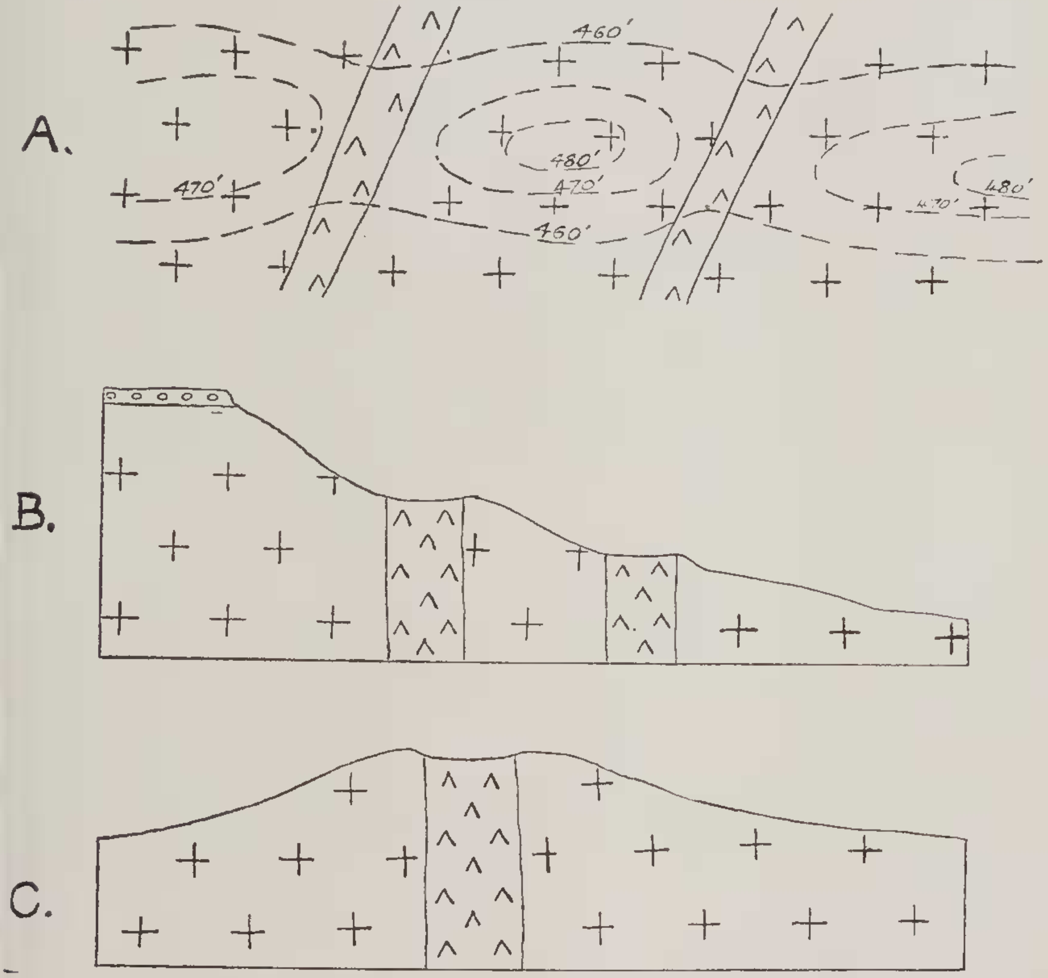
II. PHYSIOGRAPHY.

The area examined is situated on the south side of the Helena valley adjacent to the western boundary of the Darlington Area (Clarke and Williams, 1926, plate XXIII). It lies entirely on the Darling Scarp and extends from the high-level plateau, outliers of which occur in the south-eastern corner of the area, almost to the flat, low-lying country of the coastal plain to the west. It therefore covers the area represented on Woolnough's generalised section (1920, p. 20) from the Darling Plateau to the Swan Coastal Plain in the same way as the area mapped at Armadale (Prider, 1941) covers a somewhat similar generalised section of the Scarp approximately 15 miles to the south of Ridge Hill which has been published by Woolnough (1918, p. 391).

The main characteristics of the Darling Scarp have been sufficiently described by previous authors (see for example Jutson, 1934, pp. 84-87) and require no further consideration here, and attention will be confined to the topographic features of the Ridge Hill area itself.

The Drainage Pattern.—The Scarp is dissected by: (a) the westerly flowing streams, the Helena River and Farrants Creek, which are consequent streams owing their development to uplift of the Darling Plateau to the east; (b) minor streams flowing approximately parallel to the scarp which have produced the dissected foothill zone mentioned by Woolnough (1920, p. 15). Such streams are Stathams Creek draining into the Helena to the N.N.E. and the tributary of Farrants Creek draining to the S.S.W. These appear to be subsequent streams (Clarke, Prider and Teichert, 1944, p. 78) whose direction has been determined by the N.N.E. strike of the shear structures in the granitic rocks and also by the presence of epidiorite dykes. The divide between these two streams, at 15 chains south of Ridge Hill siding, is occupied by an epidiorite dyke.

The role that the epidiorite dykes play in the development of these minor topographic features of the Darling Range is of interest. In most places in the Darling Scarp area the granitic rocks are more resistant to erosion than the basic dykes which are generally represented by shallow depressions (text fig. 1A) or flattened areas on otherwise uniform slopes (text fig. 1B). Similarly at Toodyay a most noticeable feature is that the main ridges in the granite gneiss areas have a central core of dolerite but the crest of such ridges has a shallow central depression over the dolerite dyke (text fig. 1C). It is evident, therefore, that in the Darling



Text fig. 1.—*Relative resistance to erosion of granitic rocks and basic dykes in the Darling Ranges:*

A. Diagrammatic sketch plan of granite ridge at Armadale (not to scale) showing that dolerite dykes occupy the saddles in granite ridges.

B. Diagrammatic sketch section (not to scale) of upper part of the Darling Scarp at Ridge Hill showing minor flattened benches which are underlain by epidiorite dykes.

C. Diagrammatic sketch section (not to scale) of geological structure of ridges in the Toodyay District showing that although ridges are cored by dolerite dykes there is a shallow central depression.

(Granitic rocks are indicated by crosses, basic dykes by arrow heads and laterite by circles.)

Range area the basic dykes are *less* resistant to erosion than the adjoining granite and not more resistant as indicated by Aurousseau and Budge (1921 p. 35) and Clarke and Williams (1926, p. 167), but at the same time they have contact metamorphosed the adjoining granite slightly thus rendering it more resistant to erosion than the unaffected granite at some distance from the basic dykes, thus accounting for the anomalous behaviour of the less resistant basic dykes forming the ridges. This observation of the relation of topography to the less resistant dykes is of some importance in geological mapping in the Darling Range area—if shallow gullies or depressions are examined more closely it will generally be found that the underlying rock is either basic dyke rock or else sheared granite.

The Darling Plateau capped by the high-level laterite is exposed in several outliers of the plateau in the south-east corner of the area. These outliers are flat-topped and surrounded by breakaways (Clarke, Prider and Teichert, 1944, p. 60).

The Ridge Hill Shelf forms almost the entire western part of the mapped area. To the north-west of Ridge Hill siding it is laterite-covered at an elevation of 250 feet above sea level and from here it slopes down gently and uniformly to the west where it passes eventually into the flat coasal plain. It is immaturely dissected in the north-west part of the area by north-flowing tributaries of the Helena River which flows almost parallel to the northern boundary of the mapped area and at some 10 to 20 chains to the north of it.

As noted above, Woolnough considers this shelf to be the top of the downfaulted laterite-capped Darling Plateau but evidence will be put forward later in this paper which indicates rather that this shelf is actually an erosion feature such as a wave-cut bench and bears no relation to the Darling Plateau.

Clarke and Williams (1926, p. 167) have recognised *high-level terraces* in the Helena Valley just to the east of the Ridge Hill area. These terraces fall into two series, one lying at about 450 feet, the other at about 250 feet above sea level. The 250 feet series may be represented in the Ridge Hill area by the Ridge Hill Shelf and the 450 feet series by the flattened spur south from Stathams quarry, but otherwise these terraces cannot be detected in this area. The flattened spurs both in the Darlington area (with the exception of the terrace on which the village of Darlington stands) and above Stathams quarry are cored with epidiorite dykes. As has been noted above the epidiorites are less resistant to erosion than the granitic rocks—is it possible therefore that these flattened spurs or terraces are due to the differential erosion of weakly resistant epidiorite, more resistant granite and most resistant contact altered granite as indicated in text figure 1, rather than to two periods of still-stand during the uplift of the Darling Plateau?

III. GEOLOGY.

A. FIELD DISTRIBUTION AND RELATIONSHIPS OF THE ROCKS.

The diagonal joining the north-east and south-west corners divides the area conveniently into two parts. To the east and south of this line the rocks are those of the Pre-Cambrian granitic complex with associated epidiorite dykes which is overlain in the extreme south-east corner by the high-level laterite. To the north and west of this line the surface is covered by younger sedimentary rocks—a thin series of ferruginous sandstones and conglomerates—which, in the northern dissected part of the area, can be seen lying unconformably on the Pre-Cambrian rocks. This ferruginous sandstone series is in turn overlain by a thin crust of laterite and is bounded to the west by sandplain country which slopes gently and uniformly down to the coastal plain still farther west. An attempt has been made in the course of the mapping to differentiate between actual outcrop of the ferruginous sandstone series, the detritus (talus) derived from the weathering of this series, the sandy and pebbly soils overlying the ferruginous sandstones and low-level laterites, and the sandplain country underlain by yellow sand. The areas occupied by these various formations are indicated on the accompanying geological map (Plate 1).

B. THE PRE-CAMBRIAN ROCKS.

These include granites, sheared granites (sericite schist), epidiorite and quartz veins.

(1) *The Granites* are the basement rocks and form a complex of two main types—a coarse-grained porphyritic type with a slightly gneissic structure, and a finer even-grained type with no trace of banding. In addition end-phase pegmatites (graphic microcline pegmatites) are also to be found. It was found impossible to map the two different types of granite separately but the relations between the two can be clearly seen in the freshly exposed surfaces in Stathams quarry. In the south-western corner of this quarry large angular xenolithic blocks of the coarse-grained porphyritic and slightly gneissic granite occur in the massive finer-grained granite, thus indicating that the latter is the younger.

The younger of these two granites exposed in Stathams quarry is very similar to the Younger Granite of Canning Dam which has been fully described in an earlier paper (Prider, 1945, p. 112) and no further petrographic details are required here. There is, however, some difference between the older granite of Stathams and the hybrid gneisses (Older Granite) of Canning Dam—the Older Granite from Canning Dam generally has a migmatitic structure and is free from microcline whereas the older granite phase at Stathams has no migmatitic structure and contains abundant microcline. It is similar in mineralogical composition to the younger granite but differs from it in being much coarser-grained and slightly gneissic. Phenocrystal microcline in well-shaped crystals to one cm. or more diameter is an abundant constituent and the peripheral zone one or two mm. wide of such phenocrysts consists generally of micropegmatite. The microclines contain inclusions of sericitised oligoclase and clotted biotite flakes which are the most abundant constituents of the groundmass. The slight gneissoid structure of these granites is due to the sub-parallel flow orientation of the microcline phenocrysts. In some places this primary flow structure is very well developed, e.g., at 17 chains south-east from the centre of Stathams quarry it strikes 55°.

In view of the close similarity in mineralogical composition of the fine-grained granites and coarse-grained gneissoid granites of the xenoliths it appears most probable that they both belong to the same magma (the Younger Granite magma) and that the xenoliths represent an earlier crystallised flow-banded crust which has been fractured and the resultant blocks incorporated into the residual magma. There does not appear to be such a long time gap between the two granites at Stathams as there is at Canning Dam (Prider, 1945) and Armadale (Prider, 1941) and both appear to belong to the same main period of granite intrusion (the Younger Granite) the parent magma being of syntectic origin as outlined in the Canning Dam paper (Prider, 1945, p. 143).

(2) *The Sericite schists.*—All the granites of this area show, on microscopic examination, the effects of considerable stress in the form of crushed quartz and quartz with undulose extinction. The stress has been localised in certain zones along which the granite has been converted into sericite schist. These shear zones (see geological map) are distributed fairly uniformly throughout the area and all strike in a N.N.E. direction and dip steeply to the east. The best developed of these shear zones is exposed in the railway cutting near the 18-mile peg. The cleavage surfaces of the schist from this well developed shear zone are traversed by innumerable minute corrugations which are arranged horizontally—unfortunately these tiny drag structures are not sufficiently well developed to enable any positive determination of the nature of the earth movements responsible for the shearing. Since these corrugations are arranged horizontally the movements appear to have been dominantly vertical.

There is considerable divergence between the N.N.E. direction of these shear zones and the almost due north trend of the Darling Scarp which indicates that these shears bear no relation to the supposed Darling Fault.

(3) *Quartz veins.*—These have been noted in several places. They have a general trend parallel to the shear zones and their direction has evidently been controlled by the earlier imposed shear pattern. The occurrence and petrology of the quartz veins and shear zones in the Darling Scarp have been sufficiently dealt with in previous publications (Clarke and Williams, 1926, p. 174; Prider, 1941, p. 48; Davis, 1942, p. 256) and require no further consideration here.

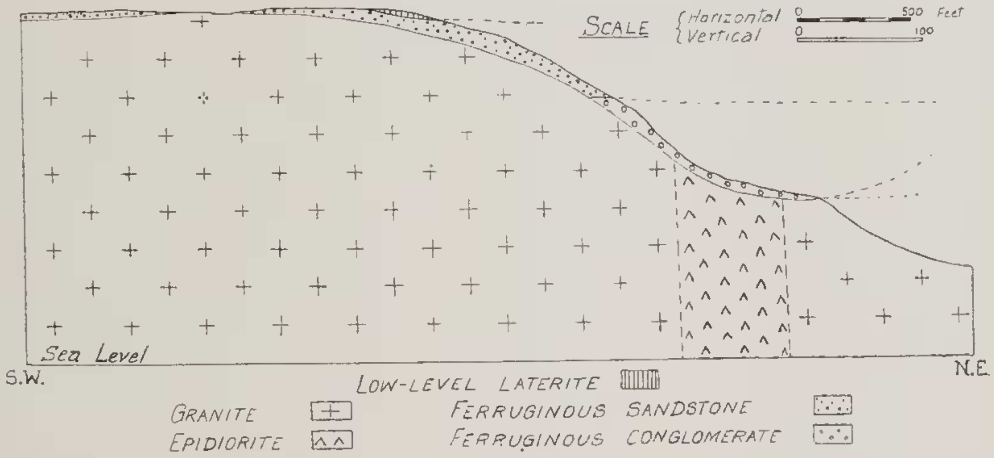
(4) *The basic dykes* also have a general N.N.E. trend following the structure of the granites. There appears to be one age only represented and all the specimens examined prove to be epidiorites consisting essentially of fibrous uralite (recrystallised around the borders of the aggregates to prismatic blue-green hornblende) and plagioclase with smoky appearance. Relicts of ophitic texture and the presence of end-phase micropegmatite point to a close relationship of these epidiorites with the quartz dolerites in other more distant parts of the Darling Range. This matter has been dealt with more fully in a previous paper (Prider, 1948, pp. 43-84).

The epidiorites have been quarried at Stathams for road metal and concrete aggregates. In the exposures in the quarry basic pegmatite segregations may occasionally be found and the occurrence of stilbite has been recorded by Simpson (1910, p. 36 and 1931, p. 36) from zeolite-calcite veins at the edges and also in the centre of the main dyke in Statham's Quarry.

C. THE LATER ROCKS.

The Later Rocks include the ferruginous sandstones and conglomerates, the high- and low-level laterites and the yellow sands of the sandplain forming an apron in front of the scarp.

(1) *The ferruginous sandstone series* forms a thin cover on the Ridge Hill Shelf where it lies unconformably on highly kaolinised granites. The unconformity is an undulating surface (see text fig. 2). The eastern contact of this series with the granite trends in a north easterly direction and thus bears no relation to the supposed Darling Fault which trends due north. In the north-west part of the area small streams have cut down through this series to expose the underlying Pre-Cambrian rocks to the west of the ferruginous sandstone outcrops.



Text fig. 2.—S.W.-N.E. section of South side of Helena Valley from the Helena Valley to the Ridge Hill shelf showing unconformity between the ferruginous sandstone series (sandstone underlain by conglomerate and overlain by low level laterite) and the Pre-Cambrian (granite and epidiorite).

The series consists mainly of ferruginous sandstones underlain in places by boulder conglomerates. Outcrops of the boulder conglomerates occur at 60 chains N. 10° E. and 67 chains N. 5° W. from Ridge Hill Siding. The slopes below the outcrop of ferruginous sandstone in the northern part of the area are strewn with well-rounded waterworn boulders which appear to have been derived from this conglomerate. These boulders have not been found in other parts of the area suggesting that the conglomerates are confined to that part of the ferruginous sandstones closest to the present Helena River. Since the known outcrops of conglomerate are at levels below the sandstones and are confined to the small area lying to the south of the Helena River it appears that they form a localised basal layer in the sandstones probably indicating an old stream channel or narrow embayment in the coast. It is interesting to note that Fletcher and Hobson (1932) have described a similar occurrence of ferruginous sandstone with rounded quartz pebbles underlying a low-level laterite in the Swan Valley at Upper Swan. This deposit they refer to as the "Older Alluvium". It occurs at an elevation of from 250 to 300 feet (the same as the Ridge Hill ferruginous sandstones).

(i) The **conglomerates** at Ridge Hill consist mainly of boulders and cobbles of granite, epidiorite and quartz, up to 18 inches diameter. All are strongly rounded and one water-worn granite boulder collected from a spot 65 chains N. 10° E. from Ridge Hill siding is a perfect ellipsoid of revolution with major diameter 11 inches and minor diameter five inches. This has the appearance of a beach boulder but it is doubtful whether such shape is indisputable proof of beach action (Wentworth, 1922, p. 82). The fact that the boulder beds are confined to a comparatively small area seems indicative of either a fluviatile origin or as an accumulation of beach boulders in a small bay. From the degree of rounding of the sand grains in the associated sandstones (to be described presently) the possibility of fluviatile origin seems remote. It appears most probable that these boulders were derived by direct marine abrasion of the nearby coast which was made up of these Pre-Cambrian rocks since the rock types noted amongst the boulders can be matched with the rocks in the Ridge Hill area.

(ii) The **sandstones** form the bulk of the exposure of this series. They are reddish in colour, have no bedding, are unfossiliferous and no certain means exist of accurately determining their geological age. They contain occasional water-worn quartz pebbles which are well-rounded and in some instances highly polished. The sand grains are almost entirely quartz and two types can be distinguished:—(a) grains with a rough irregular surface which nevertheless shows signs of considerable abrasion and (b) smooth-surfaced rounded grains with dull to polished surface textures which appear to be the result of a polish superimposed on earlier frosting. Crescentic percussion marks are generally well developed on the larger grains. A specimen (22798) of this ferruginous sandstone from three feet below the low-level laterite capping on the Ridge Hill Shelf was disintegrated by boiling in HCl and mechanical-, heavy mineral-, and shape- analyses of the insoluble residue (70 per cent. of the sample) were made. The results of these analyses are set down in Table III and in Column D of the histograms of figures five and six. The results of a chemical analysis of this specimen are recorded in Table I and the heavy mineral analyses are shown in Table V.

The main features disclosed by these analyses are:—

(a) The mechanical analysis (by hand sieving with Tyler screens) indicates that the insoluble material is fairly well graded, 48 per cent. lying between ½ and ¼ mm. diameter and 30.5 per cent. lying between ¼ and ⅛ mm. diameter. No significance should be attached to the relatively high (11 per cent.) proportion which passed 250 mesh (i.e. less than 0.061 mm. diameter) as microscopic examination shows that it consists largely of broken tuberose fragments of white material which, because of its irregular and branching forms, appears to be an authigenic mineral unrelated to the original detrital sand grains. This material is isotropic with refractive index varying between 1.52 and 1.54 and the refractive indices do not vary after ignition. It is insoluble in HCl and stains readily with malachite green. It therefore appears to be either montmorillonite or a dehydrated alumina-silica gel with $Al_2O_3 : SiO_2 = 1 : 2.8$ (Splichal, 1922, p. 288) and in view of its tuberose nature more probably the latter.* The $Al_2O_3 : SiO_2$ ratio of approximately 1 : 3 is confirmed by the chemical analysis of the rock (Table I, column 1) which shows that the rock contains alumina and combined silica in the molecular ratios 31 : 90. This material forms practically all of the minus 250 mesh fraction (11.2 per cent.) and approximately half the 115-250 mesh fraction (3.6 per cent.) but very little was present in the coarser grades and if this

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*Mr. A. J. Gaskin has recently (1947) made a thermal examination of the clayey fraction of two soil samples from over the ferruginous sandstones and low-level laterites and finds from the thermal data that they contain limonite and kaolinite (much of which is semi-amorphous) with a possibility that some gibbsite is also present.

material be disregarded it will be seen that the actual detrital material is well graded, 92 per cent. lying between ⅛ and ½ mm. diameter.

(b) Heavy mineral analyses were made of the three finest grades, the material passing 250 mesh being separated by centrifuging. The light fractions consist entirely of quartz with the alumina-silica (allophanoid) mineral. The heavy fractions were further separated into magnetic and non-magnetic fractions, the magnetic fraction (largely ilmenite) in each grade forming approximately 75 per cent. of the heavy fraction. The heavy minerals identified are recorded in Table V and of these zircon is the most abundant of the non-opaques and is worth further mention as there are two distinct varieties present, the predominant type in both the 60-115 and 115-250 mesh fractions being perfectly rounded and colourless, the other type being slightly worn to perfectly euhedral colourless to purplish zoned. This is indicative of derivation of the detrital material from two different parent rocks such as an igneous rock (e.g. granite) to yield the euhedral zircons and a sedimentary or metasedimentary rock to yield the well-rounded zircons (roundness 0.9) which have undoubtedly passed through more than one cycle of erosion. The association of these two types of zircon may indicate derivation in the one cycle of erosion from a distributive province of the nature of the present Toodyay area (Prider, 1944) which is situated in a belt of igneous and metasedimentary Pre-Cambrian rocks lying some 30 to 40 miles inland from the Darling Scarp.

(c) Visual projection roundness (Krumbein, 1941) and sphericity (Rittenhouse, 1943) values were determined for the light fractions of the 16-32, 32-60, 60-115, 115-250 Tyler mesh grades. The results (shown graphically in column D in figures five and six) indicate that the average sphericity in all fractions is approximately the same (0.83) and that the degree of rounding decreases with decreasing size but there is still appreciable rounding of some grains down to 0.124 mm. diameter. During the roundness analysis and subsequent examination of the surface texture of the grains it was evident that there are two distinct types of quartz sand grains present—a well-rounded set and another the grains of which are much more angular although still showing considerable abrasion. The proportion of well-rounded to poorly-rounded grains increases with increasing grade thus:

Grade	·124–·246 mm.	·246–·495 mm.	·495–·991 mm.
% of well-rounded grains	5	50	90

The occurrence of a small proportion of well-rounded grains in the ⅛ to ¼ mm. grade seems indicative of the derivation of the detrital material from several different sources. The high proportion of well-rounded grains in the ½ to 1 mm. grade indicates, however, very considerable abrasion during the last cycle of erosion and since this rounding is well marked down to the grains of ¼ mm. diameter it must be assumed (following Twenhofel, 1945, p. 66) that this final stage of abrasion must have taken place on a sea beach. The smaller well-rounded grains may be due to an admixture of some aeolian-transported sand with the beach sand, or may have been derived from some pre-existing sediment. No such sedimentary rocks are known to the east of the Darling Scarp, although there are metasedimentary rocks which could have yielded the well-rounded zircons but these rocks (mica schists and quartzites) would not yield directly the small well-rounded quartz grains since the quartz in these rocks has been completely recrystallised and in the rock occurs as irregular interlocking grains (Prider, 1944, p. 92).

(d) The surface texture of the sand grains of the 16 to 32, 32 to 60, and 60 to 115 Tyler mesh grades was examined with the binocular microscope in dry mounts on a dark ground for the quartz grains and on a white ground for the heavy minerals, with the following results:—

The 60 to 115 mesh grade (⅛ to ¼ mm.) consists of approximately 95 per cent. of rough irregular-surfaced grains with polished or fracture surface and five per cent. of smooth-surfaced rounded grains with polished surfaces which are often pitted but not frosted. The 32 to 60 mesh grade (¼ to ½ mm.) contains rough- and smooth-surfaced grains in approximately equal amounts. The smooth grains are well-rounded with polished (although somewhat pitted) surfaces—some grains show slight frosting and crescentic percussion marks are not uncommon. The rough-surfaced grains mostly show slight rounding and are all polished or bounded by vitreous-lustred fracture surfaces. In the 16 to 32 mesh grade (½ to 1 mm.) there is a high proportion (approximately 90 per cent.) of smooth-surfaced grains which vary from dull to polished. Most of these grains have a matte appearance due to minute pitting but this is not a frosted surface but appears rather to be the result of a polish superimposed on earlier frosting. Crescentic percussion marks are generally well developed.

Twenhofel (1945, p. 67) considers that frosting may be developed on quartz grains exceeding one mm. diameter on marine beaches but not on grains smaller than one mm. which can only be frosted by wind action. The above observations on the surface texture of the grains of the Ridge Hill ferruginous sandstone therefore are indicative of beach action.

From these considerations of the mechanical constitution, degree of rounding of the grains and their surface textures it appears most probable that the detrital materials of these ferruginous sandstones and conglomerates were deposited on a sea beach and are not fluviatile deposits. The basal conglomerate layer represents accumulations in a narrow embayment in the coastline existing at this time. The anomalous occurrence of pebbles and cobbles in the sandstones is accounted for by the close proximity to the east of the Pre-Cambrian landmass which yielded the detrital material, these boulders being the result of marine abrasion and having suffered practically no transport except on the beach.

Owing to the absence of fossils the geological age of the ferruginous sandstone series is indeterminable. It may be either—

(a) of Lower Cretaceous (?) age similar to the sandstones and leaf-bearing shales of Bullsbrook (Clarke, Prider and Teichert, 1944, p. 275) which is situated on the Darling Scarp some 16 miles north from Ridge Hill, or

(b) later than the formation of the high-level laterite (?Miocene).

The Lower Cretaceous (?) sandstones of Bullsbrook are lithologically similar to the Ridge Hill ferruginous sandstones, as they contain both angular and well-rounded sand grains. A detailed examination of the roundness and surface textures of the grains of the Bullsbrook sandstone has not yet been made.

Text figure 7 illustrates diagrammatically the structure of the Swan Coastal Plain on the assumption that the Ridge Hill ferruginous sandstone is of Lower Cretaceous age. It may be noted here that Maitland (1919, p. 6) records that the Helena River carries 22,000,000,000 gallons less past Midland Junction per annum than it does further upstream near Greenmount where it is still on the Pre-Cambrian complex. It is probable therefore that this water enters the Coastal Plain Artesian Basin through the ferruginous sandstone series. The unconformity between these Mesozoic and the Kainozoic rocks of the Coastal Plain may be of the nature of an overlap. These ferruginous sandstones, extending along the front of the Darling Scarp, may therefore be the main channel from which water is distributed to the various aquifers in the rocks, ranging in age from Lower Cretaceous to late Kainozoic (Parr, 1938, p. 71), which underlie the Metropolitan Area but, so far as is known, do not outcrop.

The period of formation of the present Ridge Hill shelf is later than that of the high-level laterite which was probably Miocene according to Woolnough (1918). It was formed when the laterite-covered plateau area to the east had been elevated to approximately 400 feet above sea level, i.e present elevation of high-level laterite (700 feet) minus the elevation of the Ridge Hill Shelf (300 feet). If the ferruginous sandstone series be of Lower Cretaceous age then it represents an exhumed Lower Cretaceous shoreline with a wave-cut bench covered with marine sands; if of post-Miocene age then it is a marine wave-cut bench with a thin veneer of beach deposits which have subsequently been cemented by iron-bearing solutions into a ferruginous sandstone.

(2) *The Laterites.*—Laterite occurs at two distinct levels—the high-level laterite in the south-eastern corner of the area at an elevation of 700 feet above sea-level and the low-level laterite on the Ridge Hill Shelf at elevations of 220 feet—280 feet above sea-level. As has been pointed out in the introduction to this paper Woolnough regards these two laterites as being of the same age and origin, their differences in elevation being due to block-faulting. Simpson (1912, p. 400) considers that, broadly speaking, there are two classes of laterite in Western Australia, firstly the primary (or high-level) laterites and secondly the secondary or low-level laterites occurring at lower levels and composed largely of mechanically transported fragments derived from the high-level laterite. I am not aware whether or no Simpson had in mind the low-level laterites fronting the Darling Scarp in his mention of secondary laterite but it seems from his description that he would regard the low-level laterite of Ridge Hill as a secondary laterite (lateritite).

Field mapping has shown that in this area the high-level laterite is developed over the Pre-Cambrian complex whereas the low-level laterite has developed over the ferruginous sandstones described in the previous section of this paper. Moreover the low-level laterite appears to be a true laterite developed in situ on the ferruginous sandstones and not a lateritite as suggested by Simpson for the low-level laterites generally.

(i) The **high-level laterite** varies in character according to the nature of the underlying Pre-Cambrian rocks. In one place in the area where it overlies granite containing quartz veins it is crowded with large quartz fragments. When developed over granitic rocks it generally has a pisolitic structure and is comparatively light-coloured but when over epidiorite (as at the northern end of the high-level laterite outlier in the south-east corner of the area) there is no pisolitic structure but the rock is somewhat cellular and appears to be richer in iron, these iron oxide patches being compact, fine-grained and massive. All the high-level laterites are underlain by a highly weathered (kaolinised) zone which passes down into the unweathered country rocks as described by Simpson (1912). Analyses of two high-level laterites are given in Table I, cols. III and IV. Analysis III is of a laterite developed over epidiorite from the Ridge Hill area. Analysis IV quoted from Simpson (1912, p. 404) is from Gooseberry Hill which is situated approximately one mile south of the Ridge Hill area, but no details of the exact locality are available. Through the courtesy of the Government Mineralogist and Analyst (Mr. H. Bowley) I have been able to examine Simpson's analysed specimen—it is a dense reddish-brown rock with numerous iron-rich concretions scattered uniformly throughout. The Ridge Hill specimen (Analysis III) is a dense brownish coloured rock with occasional cavities producing a slightly cellular structure but concretionary structures are absent. Chemically the two rocks differ in the lower Fe/Al ratio of the Gooseberry Hill rock.

TABLE I.

ANALYSES OF FERRUGINOUS SANDSTONE AND LATERITES FROM RIDGE HILL.

	I.	II.	III.	IV.
SiO_2*	63·93	44·87	10·30	6·41
Al_2O_3	3·17	24·63	22·53	36·74
Fe_2O_3	27·63	14·82	48·56	39·80
TiO_2	0·99	1·25	3·24	1·98
MnO	0·02	0·01	0·05	0·06
H_2O†	4·40	14·61	15·82	14·93
Others	...	...	...	0·51
	100·14	100·19	100·50	100·43
*Combined SiO_2	5·42	8·18	4·94	1·97

†Loss on ignition.

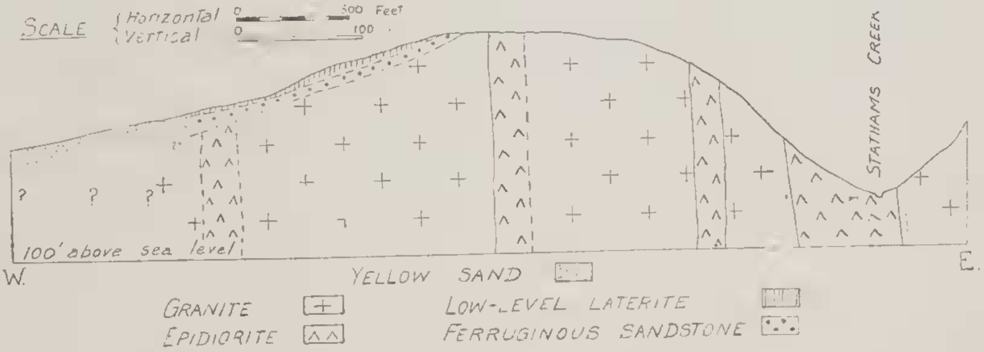
I. Ferruginous sandstone (22798), three feet below laterised surface rock in quarry 25 chains north of Ridge Hill Siding, W.A. (*Anal.* R. T. Prider.)

II. Low-level laterite (21359) overlying ferruginous sandstone, from quarry 25 chains north of Ridge Hill siding, W.A. (*Anal.* R. T. Prider.)

III. High-level laterite (22797) from northern end of outlier of the high-level laterite, 45 chains south-east of Ridge Hill siding, W.A. (*Anal.* R. T. Prider.)

IV. High-level laterite, Gooseberry Hill, W.A. (no further locality details available), (Simpson, 1912, p.404.)

(ii) The **low-level laterite** occurs as a thin discontinuous layer above the ferruginous sandstones on the Ridge Hill Shelf. It has, on the exposed surface, a somewhat fragmental appearance but on breaking the rock these fragments are seen to be of ferruginous sandstone identical in character with the underlying ferruginous sandstones which have been described above. These fragments in a typical specimen (21359) which has been analysed average five mm. diameter and they are coated with a dense layer of light brown, fine-grained and compact bauxitic material and the spaces between the fragments are largely filled with this bauxitic material but some cavities remain giving the rock a slightly cellular structure. This surface lateritic crust passes down into the normal ferruginous sandstone at three or four feet below the ground surface and there can be no doubt that the laterite has formed in situ from the sandstones which in turn overlie the Pre-Cambrian granitic rocks. These granites wherever exposed below the ferruginous sandstones (e.g. at 45 chains north from Ridge Hill siding) are seen to be highly weathered (kaolinised) in the same way as the granites under the high-level laterite (the relationships of these rocks are illustrated in text fig. 3).



Text fig. 3.—E.-W. section at 33 chains North of Ridge Hill siding showing relationship of the Pre-Cambrian granites and epidiorites, ferruginous sandstones and overlying low-level laterite, and the younger yellow sands.

An analysis of the Ridge Hill low-level laterite is given in Table I. analysis II where it is compared with the analysis of the underlying ferruginous sandstone (anal. I) and the high-level laterites (anal. III and IV). It differs from the high-level laterites in its much higher silica content, due largely to the presence of abundant water-worn sand grains residual from the ferruginous sandstone from which it was developed, but also in part to a higher proportion of combined silica. Comparing the composition of the low-level laterite with the underlying ferruginous sandstone the most notable feature is the marked increase during lateritisation of the Al_2O_3/Fe_2O_3 ratio and the development of the hydrated oxides such as limonite and bauxite. In a consideration of the chemical changes sustained by the parent rock during the lateritisation process the only factor which may with some degree of certainty be likely to remain constant is the quartz (free silica) content. In Table II the analysis of the laterite (column 2) has been recalculated to quartz = 58.51, i.e. these figures would then represent the number of grams of each constituent in a volume of the laterite which contains 58.5 grams of quartz. Comparing these figures with those of the parent ferruginous sandstone (column 1) the gains and losses in the various constituents per 100 grams of the original sandstone may be determined (column 4).

TABLE II.

CHEMICAL CHANGES IN THE FORMATION OF THE LOW-LEVEL LATERITE.

	1.	2.	3.	4.
	Ferruginous sandstone (Weight %)	Low-level laterite (Weight %)	2. recalculated to quartz 58·51	Gains and losses during lateritisation. (Gms/100 gms. of original rock)
SiO_2 Quartz ...	58·51	36·69	58·51	...
Combined	5·42	8·18	13·05	+ 7·63
Al_2O_3	3·17	24·63	39·27	+ 36·10
Fe_2O_3	27·63	14·82	23·63	— 4·00
TiO_2	0·99	1·25	1·99	+ 1·00
MnO	0·02	0·01	0·02	...
H_2O	4·40	14·61	23·30	+ 18·90
	100·14	100·19	159·77	Gain 63·63 Loss · 4·00
Net Gain ...	...	...	...	59·63gms. per. 100 gms. original rock.

There has been a slight loss in Fe_2O_3, slight gain in titania and combined silica but very marked gains in alumina and water. The significant changes are those in the alumina and water content and these are in the molecular proportions alumina : water = 354 : 1050 i.e., 1 : 3 so that the material added to the original rock during the lateritisation process is essentially aluminium hydroxide ($Al(OH)_3$). The source of this aluminium hydroxide is unknown—the ferruginous sandstones are poor in alumina but the alumina may have come from the underlying granitic rocks as there is only a thin veneer of sandstone, but on the other hand it may have been derived from an overlying shale or mudstone which has now been entirely removed by erosion.

The low-level laterite is therefore a true laterite, and not a lateritite, due to the accumulation of alumina in the near-surface layer, formed in situ over the ferruginous sandstone. This laterite formation probably took place shortly after the sand-covered marine bench (the Ridge Hill Shelf) was elevated a few feet above sea-level. This was later than the formation of the high-level laterite.

(3) *The Yellow Sands.*—The Yellow Sands constitute the youngest formation and are exposed in the westernmost part of the mapped area where they form an even gentle slope down to the level of the coastal plain to the west. The boundary between the yellow sands and the earlier rocks is irregular (see Plate I) thus precluding the possibility of a faulted contact or fault scarp against which the sands have accumulated. There is an abrupt change from the ferruginous sandstone and low-level laterite to the yellow sands and this has been well exposed by rainwash in a drain on the south side of the railway line at seven chains south-west from the 14-mile peg. Over the laterite this drain is two feet deep but on reaching the boundary with the incoherent yellow sand it deepens abruptly

to about 12 feet. Downstream from this point the gulley continues as a narrow washout four feet wide by 12 feet deep which is roofed by the roots of the adjacent jarrah trees (text fig. 4).

Text fig. 4.—Washout in yellow sand, seven chains south-west from the 14-mile railway peg. The very recent development of this feature is evident from the uncovered roots of the nearby jarrah trees.

The yellow sand profile exposed consists of 12 to 18 inches of light grey sand with plant roots, the remainder of the profile consisting entirely of yellow sand in which there is absolutely no sign of bedded structure, the whole profile consisting of sand of uniform texture from top to bottom of the exposed section. Throughout the sand at intervals of several inches are small nodules of more compact material averaging ½ inch diameter which project from the vertical sand face. These nodules which can be cut through with a knife consist of the sand weakly cemented with reddish iron oxide. On cutting a fresh surface with a hatchet they appear only as reddish iron-stained spots with a gradual transition to the yellow sand. It is only where they have been exposed to the atmosphere on the walls that a slightly hardened surface has been formed on them. At the bottom of the section exposed in the washed out drain the sand contains an abundance of these nodules, in some places aggregated to nodules several inches in diameter. These larger aggregates are weakly cemented and can be broken across with the fingers. They contain a higher proportion of fine-grained, light brownish to greyish clayey material. They appear to have been enriched in alumina with respect to the surrounding sand and if this material which in places was slightly damp were desiccated it would be similar to non-concretionary laterite. It would appear then that with the development of these aluminous nodules at the base of the exposed profile and of the small iron-stained patches throughout the mass of the sand incipient lateritisation is taking place within this sand deposit.

The yellow sand throughout the mapped area appears to be constant in character, wherever exposed in small pits the profile is similar, i.e. a thin surface layer of grey sand underlain by the structureless yellow sand. Mapping of this formation was facilitated by the numerous small anthills of bright yellow sand brought up from below the surface grey sand. The yellow sand possesses the ability to stand up in vertical walls such as the walls of a pit and in this respect and in its structureless profile it very closely resembles the yellow sand deposits of the Perth Metropolitan Area.

What is the origin of this sand? It is (i) a residual sand derived from the low-level laterite and ferruginous sandstone, (ii) a deposit of the same origin as the yellow sand of the Metropolitan Area or (iii) an aeolian deposit against the Darling Scarp?

These various hypotheses were tested by making mechanical analyses, heavy mineral separations, shape analyses and an examination of the surface textures of the sand grains of the Ridge Hill yellow sand (two samples) and a yellow sand from the vicinity of the Department of Geology at Crawley (since no data exist concerning the yellow sand of the Metropolitan Area), on the lines described above for the acid-insoluble fraction of the Ridge Hill ferruginous sandstone. The results of these determinations are set down in Tables III, IV and V and the histograms of figures five and six.

Trask (1932, p. 72) considers that if the coefficient of sorting is less than 2.5 the sample is well sorted—all the samples examined (see Table IV) therefore are well sorted. Moreover in all cases the maximum sorting lies slightly on the fine side of the median as evidenced by the co-

TABLE III.

MECHANICAL ANALYSIS OF YELLOW SANDS.

(hand sieving with Tyler screens.)

Grade.		% by weight of grades indicated.			
Tyler screen mesh.	Size (mm.)	A.	B.	C.	D.
5– 9	> 1·981	*Nil*	*Nil*	0·81	*Nil*
9– 16	·991–1·981	0·58	1·44	3·88	0·04
16– 32	·495– ·991	19·56	12·83	12·33	6·70
32– 60	·246– ·495	50·61	35·42	46·46	48·03
60–115	·124– ·246	22·22	26·96	23·11	30·41
115–250	·061– ·124	3·47	11·85	7·12	3·62
< 250	< ·061	3·56*	11·50*	6·29*	11·20*

*By difference.

A. Yellow sand (22804), Geology Department, Crawley.

B. Yellow sand (21364), from wall of gulley, 7 chains south-west from 14-mile peg, Ridge Hill.

C. Yellow sand (22802), north-west corner Loc. 1298, Ridge Hill.

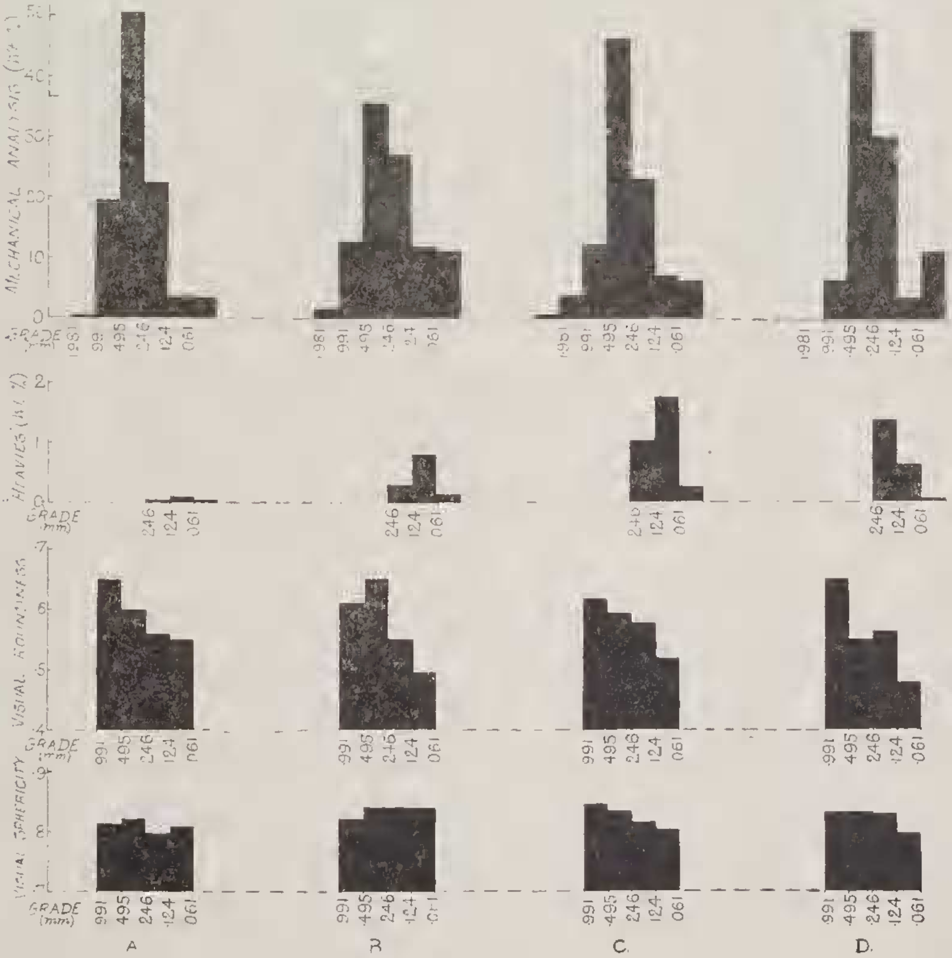
D. Acid-insoluble residue from ferruginous sandstone (22798), Ridge Hill.

TABLE IV.

First, second (Median) and third quartiles and coefficients of sorting (So) and skewness (Sk) of sands of Table III.

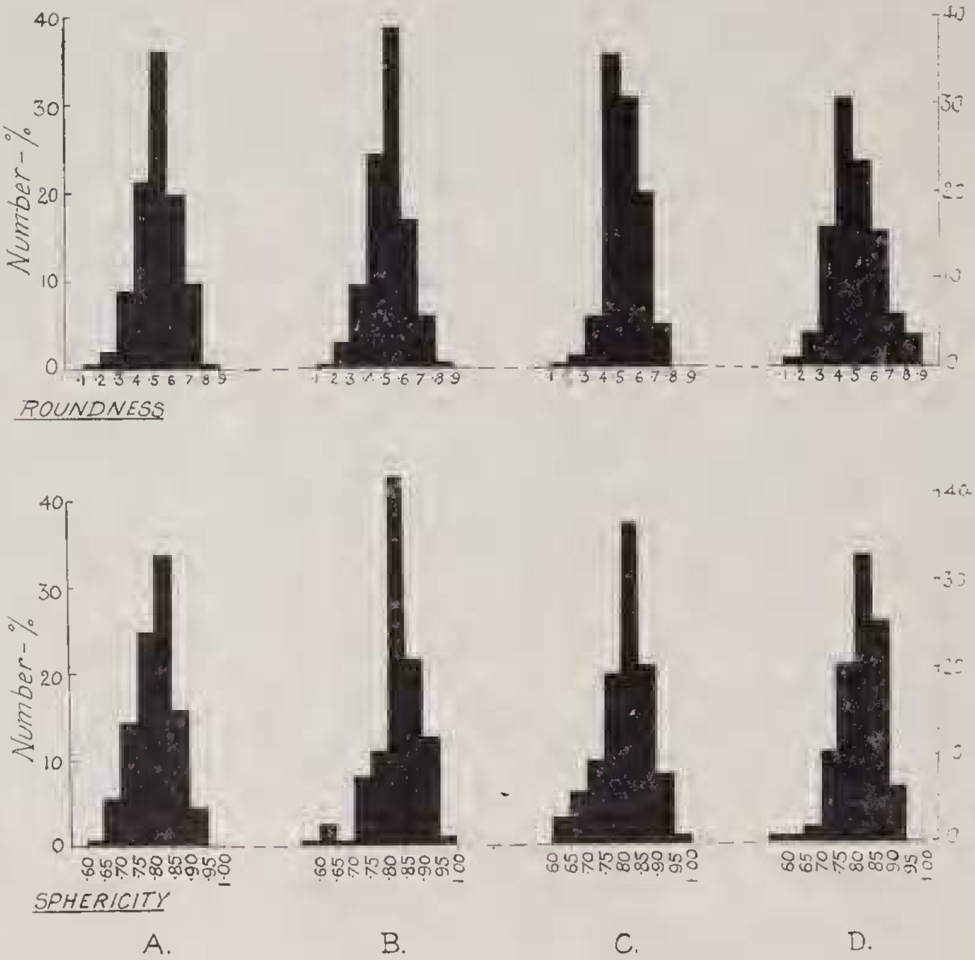
Sample.	Q3 (mm.)	M (mm.)	Q1 (mm.)	So	Sk
A.	·469	·341	·225	1·444	·907
B.	·417	·243	·130	1·791	·918
C.	·450	·318	·194	1·523	·863
D.	·384	·263	·172	1·494	·954

efficients of skewness (Table IV). If the secondary allophanoid of the ferruginous sandstone be disregarded it will be seen that the grading of the detrital material of the ferruginous sandstone is of still higher degree than that of the yellow sands. The mechanical analyses indicate that



Text fig. 5.—Histograms showing:—(1) Mechanical composition. (2) Heavy mineral content. (3) Average visual projection roundness in different grades (50 grains measured in each grade). (4) Average visual projection sphericity in different grades (50 grains measured in each grade) of:—

A. Yellow sand, Crawley, W.A. (22804).
B. Yellow sand, Ridge Hill, W.A. (21364).
C. Yellow sand, Ridge Hill, W.A. (22802).
D. Insoluble residue in ferruginous sandstone, Ridge Hill, W.A. (22798).



Text fig. 6.—Histograms of visual projection roundness and visual projection sphericity (based on measurement of 200 grains) of:—

A. Yellow sand, Crawley, W.A. (22804).
B. Yellow sand, Ridge Hill, W.A. (21364).
C. Yellow sand, Ridge Hill, W.A. (22802).
D. Insoluble residue in ferruginous sandstone, Ridge Hill, W.A. (22798).

there is some variation in the mechanical composition of the Ridge Hill yellow sand. There are no available data concerning the variation in composition of the metropolitan yellow sand. In their mechanical composition all the samples examined are very similar. The ferruginous sandstones however contain, as has been noted above, an allophanoid with tuberose form—this material is absent from the yellow sand. That this allophanoid persists in the soils formed over the ferruginous sandstones and low-level laterite is evidenced by its presence in the pebbly and sandy soil overlying the low-level laterite or ferruginous sandstone from a locality five chains south-west from the 14-mile peg on the railway line i.e. two chains east of the eastern boundary of the yellow sand. The presence of this allophanoid in the soils over the ferruginous sandstones and low-level laterite and its absence in the yellow sand two chains farther west indicates that the yellow sands are not residual deposits from the ferruginous sandstone series.

The heavy mineral separations indicate that the yellow sands of Ridge Hill contain a much higher proportion of "heavies" than the Crawley sand but in both the Ridge Hill and Crawley sands the "heavies" tend to be concentrated in the 115-120 mesh grade whereas in the ferruginous sandstone they are most abundant in the 60-115 mesh grade (see text fig. 5). The minerals present in the heavy fractions of all samples examined appear, except for the abundance of epidote in the Crawley sand, to be similar (Table V) even to the varietal features, indicating a common provenance for all samples.

Notes on the Heavy Minerals.—The magnetic fraction consists partly of strongly magnetic *magnetite* and partly of weakly magnetic *ilmenite*. The dominant constituents of the non-magnetic fractions of all samples are opaque minerals of which *leucoxene* is predominant. The leucoxene is cloudy and slowly soluble in hot sulphuric acid, the resulting solution yielding positive tests for titanium.

The non-opaque minerals are:—

Zircon. This is the predominant non-opaque mineral in all samples examined. There are two distinct types: (a) perfectly rounded, colourless and (b) enhedral prisms which may occasionally show signs of slight abrasion. The enhedral type includes colourless, colourless with rodlike inclusions, deep purple, and pale yellowish zoned varieties. The purple zircons are particularly characteristic of the Ridge Hill ferruginous sandstone but some occur in the yellow sand of the Coastal Plain. All samples contain both well rounded and enhedral types of zircon.

Kyanite is also present in all the samples examined. Generally colourless but a few grains of blue kyanite were noted in the residue from the ferruginous sandstone. The kyanite occurs in stout prisms and tablets with well rounded terminations.

Staurolite in pleochroic yellow-brown granules of somewhat irregular shape never shows the high degree of rounding of the zircon and kyanite. It appears in all the sands examined but seems to be confined to the coarser grades.

Rutile in deep reddish brown prisms, often well rounded was noted in all samples.

Epidote was the most abundant non-opaque mineral in the Crawley yellow sand. In the other samples it was very rare except in the finest grade (- 250) of the yellow sand from the south end of the Ridge Hill area (sample C.) where it is very abundant in tiny angular grains. The epidote in the Crawley sand is in stout prisms showing very little sign of abrasion. The abundance of epidote in the Crawley sand is the main point of difference between this sand and the Ridge Hill sands.

Tourmaline, generally well-rounded, is present in all samples although never abundant. The most common variety is a strongly pleochroic clove brown tourmaline. A few greenish brown tourmaline grains were noted in sample C. (Ridge Hill).

Sillimanite was noted only in the Crawley sand and ferruginous sandstone. It is in colourless fairly stout prisms.

Hornblende is of rare occurrence and confined to the coarsest fractions examined. Both brown-green and greenish varieties were noted.

Pleonaste in well rounded, green, isotropic highly refracting grains is of rare occurrence.

TAALE V.

Heavy Minerals in Sands and Ferruginous Sandstone.

Sample	A.			B.			C.			D.		
Grade (Tyler mesh)	60–115	115–250	< 250	60–115	115–250	< 250	60–115	115–250	< 250	60–115	115–250	< 250
Total " heavies " (Wt. % of total sample)	0·04	0·12	0·04	0·30	0·80	0·16	1·02	1·76	0·26	1·35	0·60	Tr.
Magnetic (Wt. % of total " heavies ")	Not determined	69	Not determined	41	70	51	76	80	63	71	77	Not examined
Non-magnetic (Wt. % of total " heavies ")	,,	31	,,	59	30	49	24	20	37	29	23	,,
	Non-magnetic fraction (figures are number-% of non-magnetic fraction)											
Opaques	Not examined	45	Not examined	80	59	69	65	49	39	54	33	Not examined
Zircon	,,	18	,,	5	34	27	15	41	6	27	54	,,
Kyanite	,,	3	,,	7	1	P	7	3	...	5	1	,,
Staurolite	,,	3	,,	4	1	....	3	1	....	5	1	,,
Rutile	,,	4	,,	1	3	3	5	5	P	6	5	,,
Epidote	,,	24	,,	.	P	....	....	P	55	P	3	,,
Tourmaline	,,	P	,,	3	1	P	4	1	.	P	1	,,
Sillimanite	,,	5	,,	....	....	....	....	....	....	1	P	,,
Hornblende	,,	P	,,	P	....	...	P	P	..	..	...	,,
Pleonaste	,,	....	,,	P	....		P	....		P	..	,,
Garnet	,,	P	,,	...	....		P	....		....	....	,,
Monazite	,,	....	,,	P	....	....	P	P	....	1	2	,,

Separations were made from original samples of 50 gms.
Number % of non-magnetic fractions based on count of between 300 and 400 grains in each sample. P indicates presence in amounts less than 1%.

A. Yellow Sand, Crawley (22804).
B. Yellow Sand, from wash-out near 14-mile peg, Ridge Hill (21361).
C. Yellow Sand, N.W. corner Loc. 1208, Ridge Hill (22802).
D. Insoluble residue from ferruginous sandstone (22798), Ridge Hill.

Garnet is also very rare, in rounded colourless to pale pink grains.

Monazite in perfectly rounded, pale yellow grains is most abundant in the ferruginous sandstone, but even there is comparatively rare.

Shape analyses indicate that all samples show similar characteristics. As indicated in figure six the average sphericity is constant in all grades for each of the samples examined and the average roundness decreases with diminishing grain size in all samples. Figure six shows the distribution of sphericity and roundness in the whole sample and it will be noted that there is a greater spread in the degree of rounding of the grains of the ferruginous sandstone than in the yellow sands—this is the only appreciable difference in the shape analyses. The similarity in the various samples indicates that so far as the factors affecting shape are concerned they all had a common type of origin.

Examination of the surface textures of the grains in these different samples revealed the following:—

Sample and Grade.	SURFACE TEXTURE		
	60–115 mesh. ($\frac{1}{8}$–$\frac{1}{4}$ mm.)	32–60 mesh. ($\frac{1}{4}$–$\frac{1}{2}$ mm.)	16–32 mesh. ($\frac{1}{2}$–1 mm.)
A. 22804 Yellow sand, Crawley.	5% of grains well rounded, smooth, high polish, but a few grains are frosted. 95% rough, vitreous fracture surfaces. "Heavies" show marked rounding and high polish	40% smooth, frosted with later superimposed polish. 60% rough, vitreous fracture surfaces	90% smooth, frosted crescentic percussion marks common. 10% rough, vitreous fracture surfaces
B. 21364 Yellow sand. Ridge Hill.	5% well rounded, smooth, polished, few grains frosted, some with percussion marks. 95% rough vitreous fracture surfaces. "Heavies" show marked rounding and high polish	Higher proportion of smooth grains than in 60–115 grade. Smooth grains frosted but some are polished. Rough grains slightly frosted	80% smooth, all frosted with slight superimposed polish. Percussion marks common. 20% rough, polished to slightly frosted
C. 22802 Yellow sand, Loc. 1298, Ridge Hill.	5%–10% well rounded, smooth, polished to slightly frosted. 90%–95% slightly rounded, rough, polished or vitreous fracture surfaces	Similar to 60–115 grade but much higher proportion of rounded grains with slightly higher degree of frosting. Crescentic percussion marks on many rounded grains	Similar to 32–60 but degree of frosting on rounded grains is higher. A polish seems to be superimposed on the frosting. Percussion marks common on rounded grains
D. 22798 Insoluble residue from ferruginous sandstone Ridge Hill	5% rounded, smooth, polished, often pitted but not frosted. 95% rough, polished or vitreous fracture surfaces. Contains small amount of tuberose allophanoid	50% rounded, smooth, polished, often pitted, a few grains frosted, some with crescentic percussion marks. 50% rough with polished or vitreous fracture surfaces	90% rounded, smooth, dull to polished with minute pitting and crescentic percussion marks. 10% rough with polished or vitreous fracture surfaces

The examination of the surface textures indicates that the fine sand grains of the ferruginous sandstone show no appreciable frosting. In the yellow sands on the other hand frosting is common down to grains ¼ mm. diameter. Moreover all the yellow sands exhibit similar features so far as the surfaces of the grains are concerned, the proportion of rounded grains and the degree of frosting of such grains increasing with increasing grain size.

The yellow colour of the sands is due to a very small amount of iron. When the yellow sand is heated it changes to a brick red colour. Determinations of the iron content responsible for the yellow colouration of the Crawley and Ridge Hill sands were made by first removing the magnetic minerals (magnetite and ilmenite) and leaching the residue with warm HCl and determining the iron content of the material leached out. The results were as follows:—

Yellow sand, Crawley (22804): 0.39% Fe_2O_3.

Yellow sand, Ridge Hill (21364): 0.48% Fe_2O_3.

From the above considerations of mechanical composition, heavy minerals, shape and surface texture of grains, the ferruginous sandstones, in view of the absence of frosted surfaces on the fine sand grains and the presence of the tuberose allophanoid, together with the different size distribution of the heavy minerals and the better grading than the yellow sands, must be regarded as differing in mode and time of origin from the unconsolidated sands. Their provenance however (as evidenced by the heavy mineral species) was similar to that of the yellow sands. In all ways except in their higher heavy mineral content the yellow sands of Ridge Hill are similar to the only examined sample of yellow sand from the Metropolitan Area and each of these must, until further evidence to the contrary be brought forward, be regarded as belonging to the same formation. The presence of frosting on grains less than one mm. diameter (grains down to ¼ mm. are frosted) is indicative of aeolian transportation (Twenhofel, 1945, p. 67). The yellow sands of the Metropolitan Area have not previously been examined in detail although Esson (1926, p. 14) suggests that they are dune sands. It may rather be that they are residuals from the disintegration of the Coastal Limestones. Pending further investigation it is impossible to say whether the yellow sands of Ridge Hill are sands blown from the sea beach and banked up against the Darling Scarp or are residual deposits from the Coastal Limestones (in which the sand grains may prove to have suffered aeolian transport). The complete absence of bedded and other structures in these yellow sands seems to indicate the latter. The observation that the Ridge Hill sands have a much higher heavy mineral content than the yellow sands of the Metropolitan Area also seems to indicate that the sands fronting the scarp are residual rather than sands blown from the west, in which case they would be expected to have a lower heavy mineral index than the sands of the Metropolitan Area. If the Ridge Hill sand be residual from the Coasal Limestone Series it means that the Coastal Limestone once covered the entire plain in this region or that there were belts of coastal limestone representing successive shore lines.

IV. SUMMARY AND CONCLUSIONS.

(a) *Geological history.*—The geology of the area has been described and the geological history may be summarised as follows:—

(i) The oldest rocks exposed are granites, of which there are two main phases:—a coarse-grained porphyritic and slightly gneissic granite and a medium even-grained massive granite. The gneissic type is the older of the two but both are considered to be comagmatic and to belong to the Younger Granite period (late Archaeozoic).

(ii) The granites have been considerably sheared after their emplacement. These shears, because of their Pre-Cambrian age, cannot be related to the hypothetical Darling Fault.

(iii) In Proterozoic times igneous activity is represented by the intrusion of epidiorite dykes.

(iv) There is a complete blank in the succession until late Mesozoic times at least when it is probable that the ferruginous sandstones were deposited on a wave-cut platform and that the eastern boundary of the ferruginous sandstone series represents the shore-line in these times.

(v) The next event recorded is the formation of the high-level laterite on a peneplaned surface, probably in Miocene times.

(vi) An uplift of the area of the order of 400 feet took place in late Miocene times and differential erosion of the soft rocks (Mesozoic and later) to the west and the hard rocks (Pre-Cambrian) to the east led to the formation of a low lying coastal plain (the Ridge Hill Shelf) or alternatively, if the ferruginous sandstones are not of Mesozoic age, the development by marine erosion of a marine platform (the Ridge Hill Shelf) covered with a thin veneer of beach deposits which have later been cemented with ferruginous material to yield the ferruginous sandstones and conglomerates.

(vii) The area was then elevated slightly until the Ridge Hill Shelf stood slightly above sea-level and the low-level laterite developed in situ on this newly emerged terrain.

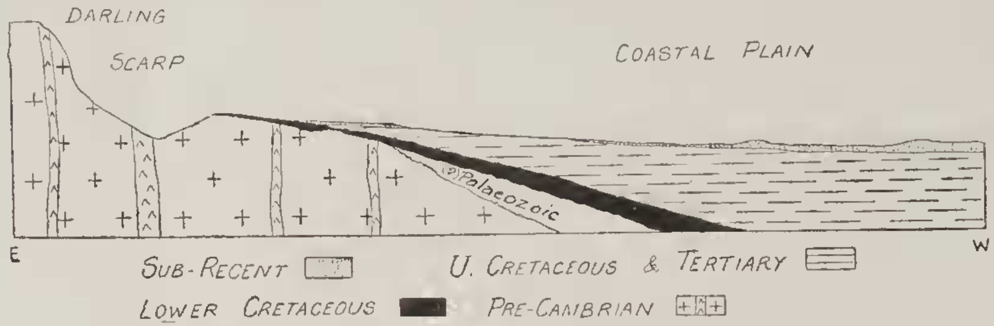
(viii) The area has since been raised approximately 250 feet, after which much of the ferruginous sandstone series was removed by erosion, especially that part which previously extended across the present Helena valley.

(ix) Contemporaneously with these upward movements of the plateau to the east there was continual subsidence (downwarping) of the area lying to the west of the Scarp and deposition in this subsiding trough of the Tertiary deposits of the Swan Coastal Plain.

(x) In comparatively recent times the yellow sands have accumulated either as aeolian deposits blown against the erosion escarpment capped by the low-level laterite or by deposition of the Coastal Limestone formation against this escarpment and the subsequent leaching of the calcareous cement yielding the structureless, unconsolidated yellow sands. As has been indicated on a previous page these sands are not residual from the disintegration of the ferruginous sandstones.

(xi) Laterite formation appears to be taking place within the yellow sands at the present day.

The structure of the Darling Scarp and Coastal Plain based on the assumption that the ferruginous sandstone series is of Lower Cretaceous age is shown diagrammatically in text fig. 7.



Text fig. 7.—Diagrammatic section (not to scale) of the Coastal Plain artesian basin on the assumption that the Ridge Hill ferruginous sandstones are of Lower Cretaceous age (comparable with the Bullsbrook sandstones).

(b) *The Darling Scarp.*—Previous authors have considered that the "fault" hypothesis for the origin of the Darling Scarp is supported by evidence of shear structures in the Pre-Cambrian rocks (Saint-Smith, 1912, p. 71; Blatchford, 1912, p. 59) and by the high and low- level laterites which were considered to be an indication of block faulting (Woolnough, 1920, p. 16). The main conclusions drawn from the evidence set down in this paper are:—

(i) There are no structures in the Pre-Cambrian rocks which can be related to the supposed Darling Fault. The shear structures are considered to be of late Archaeozoic age since some of them have been replaced by quartz veins which are intruded by late Pre-Cambrian epidiorites, and hence much older than the postulated Darling Fault. Moreover they deviate very considerably from the direction of the Darling Scarp.

(ii) The high- and low-level laterites were formed at different periods and are no indication of block faulting and therefore yield no evidence in favour of the Darling Fault hypothesis.

(iii) It has been shown that no fault exists between the eastern and western edges of the area mapped and therefore if the Darling Fault exists it must be situated some distance to the west of the Ridge Hill Area where it is covered by the yellow sands.

If these conclusions are valid there is no positive evidence for the existence of the Darling Fault. Moreover all the observed characteristics of the scarp are explicable by differential erosion of the hard Pre-Cambrian rocks to the east and the softer later rocks to the west of the scarp.

V. ACKNOWLEDGMENTS.

The field survey work in the Ridge Hill Area was done by various parties of senior students of the University Geology Department working under my supervision and their assistance is gratefully acknowledged. I am indebted also to Professor E. de C. Clarke for assistance during the revision of the text.

VI.—LIST OF WORKS TO WHICH REFERENCE IS MADE.

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